

Development and Actuality of Life Cycle Cost Technique in China

GENG Jun-bao , JIN Jia-shan , LUO Yun , WU Yi-liang

College of Naval Architecture and Power , Naval University
of Engineering , Wuhan 430033 , P. R. China

Abstract: *Life cycle cost technique is a powerful tool to make a scientific decision and a useful method of advancing the continuable development of the society. In this paper , development course , application actuality and up-to-date research trends of life cycle cost technique in China are summarized. Some suggestions are given on how to generalize the application of life cycle cost technique , which are used as the reference to study life cycle cost technique.*

Key words: life cycle cost technique; development course; application actuality; up-to-date research trends

1 Introduction

Life cycle cost (LCC) is the cumulative cost of a product over its life cycle , which includes not only the direct cost , but also the indirect cost. Life cycle cost technique is the technique related to life cycle cost , which is not only a technical economic subject but also a powerful tool to make a scientific decision. Life cycle costing is the process of economic analysis to assess the total cost of acquisition , ownership and disposal of a product. The analysis provides important inputs in the decision-making process in the product design , development , usage , and disposal. Life cycle costing can also be effectively applied to evaluate the costs associated with a specific activity , for example , the effects of different maintenance concepts/approaches , to cover a specific part of a product , or to cover only selected phase or phases of a product's life cycle.

The original idea of life cycle cost appeared in the Sweden railroad system. Since the concept was put

forward in America in 1929 , the life cycle cost technique has developed very slowly until 1960s , however it has developed rapidly from 1960s to 1980s. Several guides on life cycle cost estimation were established in America. The book named design and management of life cycle cost was published by sweden maintenance association. The LCC committee was set up by Japan Engineer Association. ISO draft life cycle cost evaluation-concept , program and application was issued by IEC in november of 1987. Since 1980s , LCC technique has been at the phase of advancement and application.

The research of the LCC technique starts relatively late in china.

This paper introduces the situation of the life cycle cost techniques in china , including the process of developing , application , the latest development of study and development trend.

2 Development course of life cycle cost technique in China

The work to carry out life cycle cost technique in China can be divided into three phases. The first one is

Received 26 February 2012

This paper is supported by the National Postdoctoral Science Foundation of P. R. China under Grant No. 20080431380

when LCC technique was indraughted and assimilated. The second one is that LCC technique was lucubrated step by step. The third phase is that LCC technique is applied widely and its theory system is perfected.

2.1 The introduction and assimilation phase

Some departments and experts attached much importance to LCC technique which has been regarded as a new project in 1970s. LCC technique began to be introduced into China in small scale. According to the demand for device management modernization ,device life cycle cost committee of China device management association (for short LCC committee) was established on 18 Sept. 1987 and was administered by economic management college of Tsinghua University. On 1989-11-18 , LCC committee was taken over by naval engineering college (the former of the Naval Engineering University) . By collecting , interpreting and concluding the data related to LCC technique , LCC technique was introduced into China. By learning exchange , curricular studies and referring to references , LCC technique was assimilated.

1) Introduction of LCC technique

The book entitled named life cycle cost evaluation-method and instance was interpreted by China Machine Press in 1984 , which was the first technical reference about LCC technique. The book entitled logistics engineering and management was interpreted by China Prospect Press in 1987 , which afforded the concept of LCC and cost model. The book entitled foreign navy ship life cycle costing was interpreted by China Ocean Press , which introduced some economic analysis method on system wide and life cycle for foreign navy ships.

2) Assimilate LCC technique by learning communion , curricular study and monograph publication the-

assimilation of LCC technique the first life cycle cost oseminar was held by LCC committee in Wuhan in November of 1990. The second life cycle cost learning meeting was held by LCC committee in Guilin in October of 1992. These meetings on LCC facilitate the development of LCC technique in China. To publicize the technique of LCC , LCC committee had held a lot of learning classes for many big corporations , which have promoted the development of LCC technique of big corporations. Many books related to LCC began to be published. The book entitled device life cycle cost and application was published by China Ocean Press in October of 1992 , which was compiled by Lu Yun , Zhang Junmai , Wu Yiliang and so on. This book has been published with copies a total circulation 10 thousand copies and has been used up. The book entitled product life cycle cost evaluation was published by National Defense Industry Press in 1993. The journal entitled China plant management launched the LCC column , which has promoted the development of LCC technique.

2.2 Deep study phase

After introduction and assimilation of the LCC technique , there was a straight acquaintanceship in military system and local enterprises. Ideas like life cycle , system wide be and whole cost have been accepted. To allommodate to the situation of China , the LCC technique need to developed and innovated , that is to say , LCC technique theory has gone into deep study phase. In this phase , various standard related to LCC have been published and some scientific study items have been made.

The first military standard GJB1364-92 equipment cost-effective analysis related to LCC was published by the National Defense Science Technique Committee in July of 1992. From 1994 to 1999 , many military

standards , such as GJBz20517 weapon equipment life cycle cost evaluation , GJBz20463 “Military Radar Life Cycle Cost Evaluation Handbook” , and GJBz 20456-97 “electron counter Life Cycle Cost Evaluation” , GJB2116-94 “Weapon Equipment Work Breakdown System” , and GJB2258-94 “Naval Ship Work Breakdown System” to name a few , have been published , which indicated the work related to LCC had come into standardization construct phase.

2.3 The application and gradual improvement of technique

After approximately twenty years when LCC technique was introduced into , assimilated and studied , LCC technique idea has been accepted in China. During 21 century , LCC technique began to be applied in many fields and technique theory will be perfected. In 2006 , the first China National Standard related to LCC was published , that is GB/T19829. 1-2005/ISO 15663-1: 2000 , GB/T19829. 2-2005/ISO 15663-2: 2000 , GB/T19829. 3-2006/ISO 15663-3: 2001 Life Cycle Costing for Petroleum , Natural Gas Industry. The book entitled equipment life cycle costing and control and the book named aerial equipment life cycle cost and economic analysis were published by National Defense Press in 2008.

3 The application of LCC technique in China

As an useful tool for scientific decision-making , LCC technique has been applied in many fields , such as program layout , construct demonstration , device development , device purchase , device work , device maintenance , device discard , hazard evaluation , circumstance protection and etc. According to some literatures , the instances applying LCC technique are as follows:

1) Traffic transportation system

In transportation system , LCC technique is mainly applied to high-speed railway , city railway , shipping , plane , road construction and so on. Some instances can be described as follows.

To reduce the working cost of the high-speed railway , the main factors of life cycle cost for the high-speed railway are set up in Reference [1]. These factors can be used to ameliorate technique for the design , manufacture , use , maintenance of the high-speed railway , which can reach the goal to reduce the life cycle cost. The LCC software for railway vehicle is set up by Middle-south University of China , which helps to popularize the application of LCC technique to railway devices^[2].

City railway traffic system is a capital intensive project. To enhance the economic benefit and reduce the working cost , LCC technique can be used in railway vehicle material , supply power device , beaconage , air-condition system , self-motion elevator system and so on^[3 #].

Shipping is a kind of device with high technique and high life cycle cost. LCC technique can be used to reduce the LCC of the shipping. A prediction method for the annual occasional repair cost of the single vessel based on radial network is given in Reference [5]. A method of combined forecasting based on support vector regression is used to estimate the cost of the ship building^[6].

LCC technique is used in many sides of the plane. For example , some authors set up the relation between the life cycle cost and life of the plane^[7]. LCC technique can be applied by the reliability monitor of the plane B737 to reduce the maintenance cost^[8].

In recent ten years ,LCC technique has been applied in many highway for road surface configuration choice , road surface maintenance , road surface design and so on. The model of life cycle cost of railway surface maintenance is set up in Reference [9]. Economy property of different structure of durable asphalt pavement with rigid base is evaluated by life cycle cost analysis method. The result indicates that asphalt pavement with rigid base can prolong service life , decrease the cost of travel time prediction , vehicle traveling and accident , keep high service capacity during period of time and decrease time life cycle cost greatly in project standard periods ^[10]. The present operation pavement structure investigation in Guangdong Province uses the life cycle cost to analyze each kind of pavement structure and obtains the optimal plan , that is mixed pavement structure , which will reduce 103 Yuan per square meter to half rigid pavement structure ^[11]. By life cycle cost analysis of asphalt pavement in frozen earth , it is concluded that asphalt stabilized base structure is more reasonable and feasible to use in frozen earth ^[12]. Quantitative analysis of life cycle costs composition for asphalt pavement is made and some design suggestion is given in Reference [13].

2) Electric power system

Along with rapid development of the economy and the construction of electric power net , Shanghai electric power company has integrated PMS , ERP and LCC system. The papers related to electric power accounted for one third of the papers published in 2010 year. East China Grid Company Limited has applied LCC technique to the purchase of 500 kV transformers , which saved a lot of money for the company ^[14]. The LCC calculation models of main transformers for a transformer substation were set up in the Reference [15] and the LCC of 500 kV transformers was figured

and compared between single-phase current and three-phase current. The author in the Reference [16] set up the LCC calculation model , analyzed the main factors and offered the suggestions on how to decrease the LCC. The main factors affecting the LCC of 500 kV and 1 000 kV transformers were deduced by the Monte Carlo simulation ^[17].

3) Petroleum and chemistry plant system

LCC technique was applied to carry out device type choice , to optimize the maintenance strategy , to control the life cycle cost and etc. How to control LCC was analyzed qualitatively in every phase of oil field construction in the Reference [18]. The author of the Reference [19] introduced some typical instances on anticorrosive material choice , maintenance occasion and maintenance strategy and so on for the chemistry plant , which reduced the LCC. Since 2008 , Shenli oil Field Company has applied the LCC technique to the construction of the sea work-boat. It gained great economic benefit by applying the LCC technique in sea water pipe material choice and anticorrosive project.

4) Steel and metallurgy system

Some steel company applied LCC technique in choosing the level of the devices and confirming the safety coefficient in its second construction project , which controlled the project budget and the cost decreased by 7% . Some coke company gained evident economic benefit in refreshing the three boilers by the LCC technique.

5) Architecture system

LCC technique has been applied greatly in architecture system. With the prevalence of green architecture , keeping LCC minimum is one of the principles making the construction decisions ^[20-22]. In some bridge construction , economic evaluation based LCC

technique was put forward in Reference [23]. Based on the projects in Beijing, four air conditioning schemes are analyzed and compared in initial investment, operating cost, energy using efficiency, and atmospheric pollution effects. It is considered that applying water source heat pump can reduce initial investment, operating cost and atmospheric pollution effects when recycling cooling-water from power plant is used [24].

6) Defense system

Because the supportability of the weapons has been increasingly important, LCC technique is applied more widely and more deeply. In recent years, LCC technique was mainly applied in missile system [25], naval ships [26], artillery weapons [27], military planes [28], radar equipments [29], armored vehicles [30], uninhabited combat air vehicles [31], torpedoes [32] and so on. The model of application mainly included development cost forecast, construction cost forecast, operation cost forecast, maintenance cost forecast, LCC control and management, cost data collection and disposal, the tradeoff on reliability, maintainability and supportability, uncertainty and sensitivity analyses on the factors affecting the LCC, cost-efficiency analyses, cost-risk analyses, equipment type choice and so on.

In general, LCC technique is comparatively widely applied to electric power system, architecture system, traffic transportation system and defense system with some economic effect, but there are few data used to validate the application effect of LCC technique. From the above-mentioned, there is a certain gap to widely popularize the LCC technique in various industries.

4 Research trends of life cycle cost technique in China

LCC technique mainly comprises LCC breakdown,

LCC estimate, LCC main factors analysis, LCC sensitivity analysis, cost-efficiency analysis, LCC management, LCC software, LCC application and so on. From recent research journals and dissertations, LCC technique in China mainly includes these following aspects.

1) LCC breakdown technique study

Cost breakdown structure is used to wholly describe the composition and relation of LCC. For cost analysis people, LCC breakdown technique is the basis of cost breakdown structure definition, cost data collection and cost estimate. For the decision-makers, LCC breakdown technique can be used to offer the cost effects, which is used to compare the different projects. LCC breakdown technique affects directly cost breakdown structure, which is the basic for the cost estimate, so the research of simple and current LCC breakdown technique is one of LCC research fields.

2) LCC estimate model and forecast methods research

LCC estimate model and forecast methods will determine the precision of LCC estimate, which affects the decision-making. In order to enhance the precision of LCC estimate, some advanced techniques are used to improve estimate model and forecast methods. These techniques presently mainly include neural network [29], fuzzy theory [33, 34], grey theory [35, 36], support vector machines theory [37], rough set theory [38], principal component theory and so on [38]. The search of LCC estimation model is one hotspot of LCC technique.

3) Data collection and disposal

If the data is inaccurate, even when the model is correct, the result of estimation is also inaccurate, thus, data collection and disposal plays an important role in LCC technique. Firstly, data items must be determined in advance; data items with no relation to LCC

must be deleted. Secondly, the method and process of data collection must be chosen, which should ensure the authenticity and integrality of the data. Lastly, measures are made to deal with those abnormal data, missing data, small species data and so on^[39]. Data collection is the bottleneck of carrying out LCC work. In fact, sixty percent of LCC work is to connect and dispose data, so the research of LCC data connection and disposal is an important factor to popularize LCC technique.

4) Relation model between the device parameters and LCC.

Some parameters, such as reliability, maintainability, not only affect LCC, but also the availability of the device. The tradeoff among the parameters is one aspect of studying LCC technique. Although it is a long time to start this research, with the increasing complexity of the device function and structure, it is more difficult to construct the relation model between LCC and the parameter of the device.

5) Estimation uncertainty of LCC

There are a lot of factors relative to LCC. These data of the factors are stochastic during the operation and maintenance of the device, such as device failure time, repair time, material cost, bank interest rate and so on. The uncertainty of the factors forms the uncertainty of LCC, which brings the inaccurate result of LCC. How to decrease the uncertainty of the estimation is one aspect of studying LCC technique^[40].

6) Research of relation between LCC and some parameters such as circumstance, continuable development, greenness index.

It is one of the effective technique of advancing the sustainable development of the society to evaluate the effect of device/project on circumstance by the LCC technique. In the process of the estimation of the de-

vice/project LCC, the environmental pollution is expressed in currency. It is one technique integrating LCC technique and environment engineering, which is to perfect the LCC technique.

7) LCC software development

LCC estimation includes a lot of factors, cost elements. If the device is complicate, the workload is very large. It needs computer software aid to estimate LCC. Presently, some companies in China have used the foreign LCC software, but the effect is not very perfect. It needs too much money to purchase the foreign software of LCC. Because the management mode between China and other countries is different, there is certain difficulty in applying the foreign LCC software. It was reported that some companies independently developed some certain LCC software, but the softwares had a few function, such as no relation to device operation flow. LCC software with strong function, friendly interface and open model construction is the key to popularize LCC technique.

5 Suggestion

With the increasing shortage of resource in the world and the increasing intensity of international competition, LCC technique should be an effective measure to enhance economic profit and manage the asset. LCC technique should be accord with the circumstance in China. LCC technique should be applied in greater scope and in more simple manner. In order to attain the above roles, some suggestions are made.

1) Reinforce the organization, draw and push the LCC technique development strategy; workout LCC technique code, standard, manual and so on. Increase the degree of educating LCC.

2) Take scientific research and academic meeting. By the national and international references relative to

LCC technique , LCC technique is popularized.

3) Reinforce the research of LCC technique , prefect the LCC estimation , construct the relation between LCC and reliability , maintainability , supportability , study the LCC model including circumstance , and research on the fusion of LCC technique with other economy analysis methods.

4) Increase the digital construction of LCC. In the government and corporations , the cost database should be set up to connect , save and share information related to LCC. Develop some useful LCC softwares fit for Chinese circumstance.

References

- [1] Wang H S , Liu L Z , Wen L , *et al* , *LCC model and factors analysis in motor train unit*. The Nine National Conference of LCC Committee of China Association of Plant Management , Shanghai , 131 ~ 135 , 2010 (In Chinese)
- [2] Zhou H , Xie S C , *Life cycle cost software in railway vehicle*. Changsha Railway Academy , 9(4) : 222 ~ 223 , 2008 (In Chinese)
- [3] Chen G , *The life-cycle cost and selection of urban mass transit equipment*. City Railway Traffic Research , (5) : 26 ~ 29 , 2003 (In Chinese)
- [4] Wen Q , Zhou Q H , *UMT booking service system in life cycle cost*. City Railway Traffic Research , (2) : 8 ~ 11 , 2007 (In Chinese)
- [5] Yao Z G , Huang J D , Li Y Q , *Occasional repair cost prediction of ships on radial network*. China Ship Repair , 21 (2) : 41 ~ 44 , 2008 (In Chinese)
- [6] Wang W , Peng R H , *Application research on combined forecasting of the outlay of shipbuilding in batch*. Ship Science and Technology , 31(3) : 124 ~ 127 , 2009 (In Chinese)
- [7] Lin G M , *Study of the life and cost of military fleet during service period*. Xi'an: Northwest-ern Polytechnical University , 2005 (In Chinese)
- [8] Li Y P , Ni R , *Application of LCC idea to B737 aircraft reliability monitoring*. Journal of Shanghai University of Engineering Science , 23(1) : 90 ~ 94 , 2009 (In Chinese)
- [9] Yu J W , Huang X M , Liao G Y , *Life cycle cost analysis of expressway maintenance work zone*. Journal of Transportation Engineering and Information , 8(3) : 43 ~ 48 , 2010 (In Chinese)
- [10] Ma Q L , *Study on durable asphalt pavement structure with rigid base*. Xi'an: Chang'an University , 2006 (In Chinese)
- [11] Xiang G W , Lu D F , *Life cycle cost analysis in amber high speed pavement design application*. China Water Transport , 8(1) : 140 ~ 141 , 2008 (In Chinese)
- [12] Sang C , Zhang Y , Xu G , *Analysis of life cycle cost for asphalt pavement in permafrost zone*. Journal of Nanjing University of Technology , 29(2) : 91 ~ 94 , 2007 (In Chinese)
- [13] Liu L P , Hua X M , *Quantitative analysis of life-cycle costs composition for asphalt pavement*. Central South Highway Engineering , 30(4) : 192 ~ 195 , 2005 (In Chinese)
- [14] Yin K , Yu D S , Li L H , *Application of LCC to bidding-based purchase of 500 kV transformers*. East China Electric Power , 37(5) : 741 ~ 744 , 2009 (In Chinese)
- [15] Jiang W J , Chen H H , Shi G Y , *The Choice of main transformer of transformer station based on LCC model*. Electric power and elec-

- trician ,29(1) : 21 ~ 23 ,2009 (In Chinese)
- [16] Cui X Q , Yin L B , Fan C J , *et al* , *Study of LCC for Power transformer in modification of transformer substation*. Power System Protection and Control , 38(7) : 69 ~ 73 , 2010 (In Chinese)
- [17] Liu J , Zhang Y , Du Z Y , *Life cycle cost sensitivity analysis in AC transmission lines design*. High Voltage Engineering , 36 (6) : 1554 ~ 1559 , 2010 (In Chinese)
- [18] Yang Q Z , *Life cycle cost control of daqing oil field construction*. Oil Field Engineering , 28 (6) : 63 ~ 65 , 2009 (In Chinese)
- [19] He Y B , Jin J S , Geng J B , *Some cases of devices maintenance and material choice based on LCC in coal and medical plants*. China Plant Engineering , (9) : 31 ~ 32 , 2008 (In Chinese)
- [20] Wu Y L , *Discussion in application of LCC technique in green construction*. China Plant Engineering , (7) : 39 ~ 41 , 2008 (In Chinese)
- [21] Liu H , Zhang R , Li Z F , *Life cycle cost-benefit analysis of green building*. Construction Management Modernization , 103 (6) : 50 ~ 52 , 2008 (In Chinese)
- [22] Wang E M , Liu Y H , Bao X Y , *Research in investment decision based on the life-cycle cost of energy efficient residential buildings*. Construction Economy , (5) : 31 ~ 33 , 2010 (In Chinese)
- [23] Hao W , Chen J Z , *The economic assessment research on bridge technical rebuilding based on life cycle cost*. Journal of Lanzhou Jiaotong University , 28(3) : 25 ~ 28 , 2009 (In Chinese)
- [24] Gao Y , Fu L , Yan D , *Comparison and selection of HVAC schemes applying recycling cooling water from power plants*. HV&AC , 37 (1) : 52 ~ 54 , 2007 (In Chinese)
- [25] Zhou Y C , *Research of maintainability design of Air to air missile*. Aviation Weapon , (1) : 42 ~ 45 , 2004 (In Chinese)
- [26] Yu J X , Zhao K , Gu P , *Study on cost-effectiveness Analysis method of Vessel*. Ocean Technology , 25(1) : 94 ~ 96 , 2006 (In Chinese)
- [27] Wu H , Qing X D , Huang Y , *Research on the life cycle risk prediction of artillery weapons and equipment*. Sci-Tech Information Development & Economy , 19 (4) : 172 ~ 174 , 2009 (In Chinese)
- [28] Zhang H X , Guo J L , Li M , *et al* , *Study on integrated cost-effectiveness characteristics of military aircraft*. Aeronautic Transaction , 26 (3) : 308 ~ 314 , 2005 (In Chinese)
- [29] Zhang W , Hua X L , *A method of estimating the LCC of ground radar equipment based on BP neural network*. Journal of Air Force Engineering University , 10(1) : 52 ~ 55 , 2009 (In Chinese)
- [30] Zhang Y F , Luo Q G , *Primary exploration of the integrated of power train system in armored vehicles*. Journal of Academy of Armored Force Engineering , 19(2) : 64 ~ 69 , 2005 (In Chinese)
- [31] Lu K , Li W J , *Life cycle cost analysis of uninhabited combat air vehicles*. Journal of Northwestern Polytechnical University , 20 (4) : 663 ~ 667 , 2002 (In Chinese)
- [32] Liang Q W , Song B W , Pan G , *et al* , *The study method of life cycle cost of Torpedo*. Fire Control and Command Control , 30(3) : 14 ~ 17 , 2005 (In Chinese)

- [33] Liang Q W , Song B W , Jiang J , *Fuzzy-grey ideal point method for estimating the life cycle cost and effectiveness of torpedo*. Systems Engineering and Electronics , 28 (9) : 1375 ~ 1377 , 2006 (In Chinese)
- [34] Liang Q W , Song B W , Wu Z H , *Life cycle cost modeling of fuzzy principal component method for weapon system*. Journal of System Simulation , 17(1) : 63 ~ 65 , 2005 (In Chinese)
- [35] Liang Q W , Song B W , Wu Z H , *Data collection and grey processing method of life cycle cost for torpedo*. Computer Simulation , 24 (2) : 1 ~ 3 , 2007 (In Chinese)
- [36] Guo J Z , Song G B , Peng S X , *Analysis for operational and support cost of equipment using grey mode*. Systems Engineering and Electronics , 26(1) : 74 ~ 77 , 2004 (In Chinese)
- [37] Cong Y , *Modeling for the equipment LCC based on principal components and SVM*. Ship & Ocean Engineering , 39(4) : 165 ~ 167 , 2010 (In Chinese)
- [38] Sun L K , *Study on the processing of the LCC impact factors and the optimization of the building model methods in the parameter estimate method*. Wuhan: Naval University of Engineering , 2009 (In Chinese)
- [39] Wang B , Guo B , *Schema mapping optimization of equipment lifecycle data source*. Computer Integrated Manufacturing Systems , 15 (5) : 1031 ~ 1040 , 2009 (In Chinese)
- [40] Wu M , Wang C , Li J Y , *An analysis on the uncertainty of weaponry's LCC estimation*. Defense Science and Technique , 30(1) : 6 ~ 10 , 2009 (In Chinese)

Brief Biographies

GENG Jun-bao is now a Ph. D and an associate professor in Naval University of Engineering. His research interests include life cycle cost technology and reliability engineering. gengjb 2002@163.com

JIA Shan is now a Ph. D and a professor in Naval University of Engineering. His research interests include supportability engineering and life cycle cost technique.

LUO Yun is now a professor in Naval University of Engineering. His research interests include reliability engineering and life cycle cost technique.

WU Yi-liang is now a professor in Naval University of Engineering. His research interest includes life cycle cost technique.